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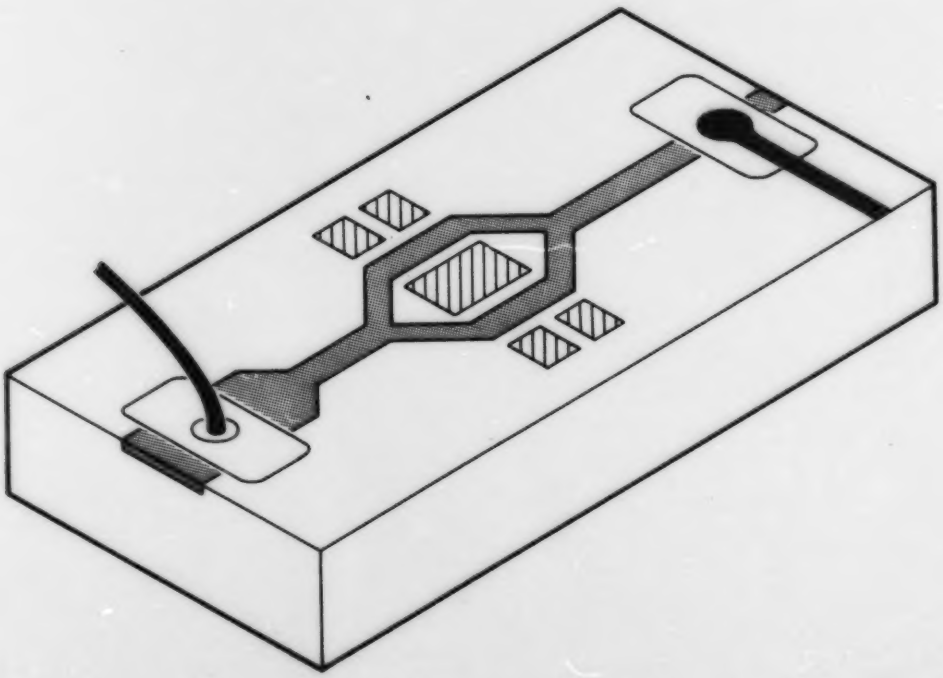
Division of Electrical Engineering
Division de génie électrique

Proceeding of the First Workshop on Integrated Optics in Canada

February 24, 1984



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Ottawa (Ontario) Canada
K1A 0R8

First Workshop on:

INTEGRATED OPTICS IN CANADA

J. Legendre
Chairman/Editor

National Research Council
Ottawa, Ontario
February 24, 1984

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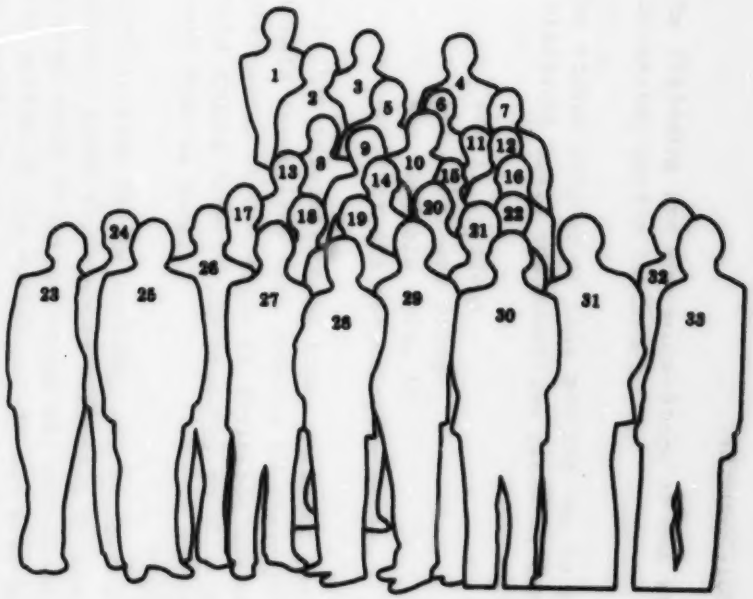


1 Dr. Elmer Hara, Department of Communications
2 Mr. N.F. Maffei, Queen's University
3 Dr. Mahesh C. Jain, Precision Photomask
4 Dr. Dolf Landheer, National Research Council
5 Dr. J.P. Legendre, National Research Council
6 Dr. Pierre Verly, National Research Council
7 Dr. Peter Sewell, National Research Council
8 Mr. John Robinson, University of Windsor
9 Dr. H. Yamauchi, University of Windsor
10 Dr. Richard Normandin, National Research Council
11 Dr. Jeff Young, National Research Council
12 Dr. A. Lightstone, RCA Inc.
13 Dr. S.B. Krupanidhi, Queen's University
14 Dr. Michael Sayer, Queen's University
15 Dr. John Lit, Sir Wilfrid Laurier University
16 Mr. Jacques Domey, National Research Council
17 Mr. Howard S. Kerr, Spar Aerospace
18 Mr. Denis K.W. Lam, Communications Research Centre
19 Mr. Grant Este, Bell-Northern Research
20 Dr. R.I. MacDonald, Communications Research Centre
21 Dr. Laszlo Andor, University of Alberta
22 Dr. Paul E. Jessop, McMaster University
23 Dr. W. Westwood, Bell-Northern Research
24 Mr. Willard Young, Litton Systems Canada Limited
25 Dr. Jacek Chrostowski, National Research Council
26 Mr. Lyall G. Rowlandson, Defence Research Establishment Ottawa
27 Dr. J.A. Dobrowolski, National Research Council
28 Dr. David Irvine-Halliday, University of Calgary
29 Dr. James N. McMullin, University of Alberta
30 Dr. J. Peter Hobson, National Research Council
31 Dr. Andrew S. Podgorski, National Research Council
32 Mr. Edward A. Vilks, National Research Council
33 Mr. Jan Bernkopf, Litton Systems Canada Limited

ABSENT: Dr. D.F. Williams, National Research Council

WORKSHOP PARTICIPANTS

INTRODUCTION

The following are the proceedings of the first workshop on the state of Integrated Optics in Canada.

The stated purpose of this meeting was to increase the awareness in this relatively small and sometimes isolated community as to:

- who is involved
- what they are doing
- why they are doing it
- how they are proposing to do it.

With this information in hand, workshop participants might be able to situate themselves with respect to their colleagues in Canada, decide if inter-group co-operation is desirable and/or possible, discuss if the field should be actively promoted in this country and, if so, how this would best be done.

Participation in the workshop was by invitation only. The intent was to severely limit the numbers attending so that an informal format could be adopted which would encourage all attendees to contribute in the discussion period of the workshop. It was also hoped that the informality of the meeting would increase, rather than otherwise, the numbers of personal contacts established. In spite of the restricted size of the meeting, it is believed that all groups working in this field in Canada were invited. Government laboratories (including two Departments and one Crown Corporation) accounted for 50% of the participants, universities very nearly 30% and the private sector the remaining 20%.

The format of the workshop was as follows: approximately one-half of the meeting was devoted to verbal presentations by a representative of each group; the balance of the workshop consisted of a round-table discussion.

The short verbal presentations were intended to summarize the projects underway or projected in the near future by that particular group or organization rather than give a detailed technical account of any particular project. The goals of the group and the facilities to which they had access were also to be highlighted. It was hoped that an awareness of these parameters would promote potential collaborative activities.

Following the individual group presentations, a round-table discussion forum was convened. Professor John Lit of Sir Wilfrid Laurier University agreed to chair this portion of the meeting and act as 'agent provocateur'.

INTRODUCTION

Voici le compte rendu du premier atelier sur la situation de l'optique intégrée au Canada.

Le but déclaré de cette réunion était d'augmenter la sensibilisation de cette communauté, relativement petite et quelquefois isolée, aux points suivants:

- qui est concerné
- que fait-on
- pourquoi le fait-on
- comment propose-t-on de le faire.

Disposant de ces renseignements, les participants à l'atelier pourraient se situer par rapport à leurs collègues au Canada, décider si la coopération inter-groupes est désirable et possible, voir si ce domaine doit être encouragé activement dans notre pays et, dans l'affirmative, quel est le meilleur moyen d'y parvenir.

Seules des personnes invitées ont participé à l'atelier. Le but était de limiter strictement le nombre des participants, de manière à pouvoir adopter une formule officieuse qui encouragerait toutes les personnes présentes à apporter leur contribution à la période de discussion de l'atelier. On espérait aussi que le caractère officieux de la réunion augmenterait le nombre des contacts personnels établis. Malgré la restriction sur le nombre des participants, on croit que tous les groupes travaillant dans ce domaine au Canada ont été invités. Les laboratoires gouvernementaux (deux ministères et une société de la Couronne) représentaient 50% des participants, les universités presque 30% et le secteur privé les 20% restants.

La formule utilisée par l'atelier était la suivante: environ la moitié de la réunion était consacré à des présentations orales par un représentant de chaque groupe; le reste de l'atelier consistait en une table ronde. Les brèves présentations orales étaient destinées à résumer les projets en cours ou prévus à court terme par un organisme ou groupe particulier, plutôt qu'à donner une description technique détaillée d'un projet particulier. Il s'agissait aussi de souligner les objectifs du groupe et les installations auxquelles il avait accès. On espérait qu'une sensibilisation à ces paramètres permettrait de promouvoir d'éventuelles activités de collaboration.

Après la présentation des groupes individuels, on a convoqué une assemblé pour une discussion en table ronde. Le professeur John Lit, de l'Université Sir Wilfrid Laurier, a accepté de présider cette partie de la réunion et de remplir les fonctions "d'agent provocateur".

ACKNOWLEDGEMENTS

The meeting was sponsored by the Division of Electrical Engineering of the National Research Council. Thanks are due Dr. J.Y. Wong, the Division's Director, for his support of this workshop. A luncheon was provided the participants which allowed everyone to remain together over the lunch period and increased the time available for personal contact. The assistance of Mr. D.M. McClymont and Mr. K. Charbonneau of the Conference Services Bureau of the N.R.C. is gratefully acknowledged as is that of Mrs. Thérèse Fournier, who cheerfully provided all the secretarial support. The group photograph was provided by Mr. D. Gamache and Mr. A. Castellano. The publication of the proceedings was arranged by Mrs. Evelyn Kidd. The support of Professor John Lit through his early encouragement of the idea of the workshop, his suggestions and his acceptance of the role of discussion moderator was much appreciated. Finally, of course, the positive response of all the participants to the suggestion that they should set aside their regular activities and travel to Ottawa in the middle of winter to have a chat on matters of mutual interest was most gratifying. It is their contributions that are here reported and to them the credit for the success of the meeting.

J. Legendre
Division of Electrical Engineering
National Research Council

June 1985

I PRESENTATIONS

SPEAKER: J.P. LEGENDRE
DIVISION OF ELECTRICAL ENGINEERING, M-50
NATIONAL RESEARCH COUNCIL
MONTREAL ROAD
OTTAWA, ONTARIO K1A 0R8
TEL. (613) 993-004

GROUP MEMBERS

Design & Testing (electrical & optical)

- J. Chrostowski 993-7908
- A. Podgorski 993-1837
- J. Legendre 993-2004

Fabrication & material characterization

- P. Sewell 993-2304
- D. Landheer 993-0560
- E. Vilks 993-2583

RESEARCH INTERESTS

Our program seeks to develop a microfabrication facility partly to generate various sensor devices. Examples are:

- a Mach-Zehnder interferometer as a broadband sensor of electric fields.

- two optical fiber based sensors of a) refractive index variations, b) surface movements (waves) with amplitudes of 0.1 nm.

- an accusto-optic bistable switch (with Laval University & University of Wisconsin).

LIST OF FABRICATION AND TEST FACILITIES

EQUIPMENT	PURPOSE AND/OR CAPABILITIES
Magnetron Sputtering System	- Deposition of metallic or insulating materials. - Capable of reactive sputtering. - Capable of sputter-etching. - Real time monitoring of film thickness and deposition rate. - Differentially pumped residual gas analyser for monitoring gas species during sputter deposition or etching. - Targets (5"x12") Ti, Ta, Al, Indium-Tin-Oxide, $LiNbO_3$.
Magnetron Sputtering System	- Two 3" diameter guns (two others under construction). - Targets: Cu, Cr, Al, Au, Nb, V, C, (LaB_6).
Single-Zone Diffusion Furnace	- Range 0-1500 °C. - Programmable 7 step temperature profile. - Chamber dimensions 2"0 x 24". - Will have controlled atmosphere.
Surface Profile Measuring System	- Calibration of film thickness measurements.
Photo-reducing facilities	- Large reduction camera will accept copy 1.2m x 1.2m. - High resolution reduction (1/10) camera max resolution 1.1µm (best achieved resolution ~3µm lines).
Photolithography	- 2µ line capability (goal is 0.5µ) - Homemade mask aligner for aligning electrodes to waveguides. - Wet etches for Al, Co, Au, Ti, Fe, Cu, Ni. - Intended to acquire an ion milling system or a reactive ion etch system.

Scanning Electron Microscope	- Structural examination.
a) with wavelength dispersive X-ray spectrometer	- Material microanalysis. - Digital scan for elemental imaging.
b) With reflection high energy electron diffraction facility (RHEED)	- Studies of surface crystallography, lattice damage, incorporated impurities.
X-Ray diffraction	
- Laue Camera	- Crystal orientation
- Debye-Sherrer camera	- Lattice constants
- READ camera	- Surfaces & thin films
Fiber Splicer	Fusion coupling of monomode and multimode fibers.

SPEAKER: JOHN LIT
WILFRID LAURIER UNIVERSITY
WATERLOO, ONTARIO N2L 3C5
TEL. (519) 884-1970 Ext. 2273

GROUP MEMBERS: 9 excluding supporting staff.

SUMMARY:

Optical fibre directional couplers, variable and fixed, and application to produce optical pulse trains; multiplexers and demultiplexers for optical communications; optical sensors; passive integrated optical components; geodesic and Luneburg lenses; thin-film optics, interference filters, reflectors and couplers with narrow bandwidths and large free spectral ranges.

LIST OF FABRICATION AND TEST FACILITIES:

EQUIPMENT	PURPOSE AND/OR CAPABILITIES
R.F. Magnetron Sputtering System	Two targets, four substrates
Thermal Heating Thin Film Evaporator	Three evaporating boats
Optical Thin Film Thickness Monitor	Monitors at 0.63 μm and 10.6 μm
CO_2 laser	Continuous 10 watts
HeNe lasers and other miscellaneous optical instruments	

SPEAKER: W. WESTWOOD
BELL-NORTHERN RESEARCH
3500 CARLING AVE
NEPEAN, ONTARIO

GUIDED WAVE OPTICS AT BNR

ACTIVITIES

- PASSIVE WAVEGUIDES
  - 1973 - Sputtered Ta_2O_5 & ZnO
  - 1974 - $LiNbO_3(T_1)$ diffused
  - 1975 - Cross-point switch design
  - 1976 - Birefringent $Ta_2O_5N_x$
  - 1979 - Can. J. Phys. Review

- III-V LASERS/MODULATORS
  - 1981 - 830nm lasers for systems
  - 1983 - 1300nm lasers for systems
  - 1984 - Integrated quaternary structures

- ACOUSTO-OPTIC SPECTRUM ANALYZER
  - 1979 - Waveguides/lenses (magnetron)
  - 1981 - SAW devices on ZnO/Si
  - 1983 - Al_2O_3 guides

FACILITIES

- III-V LASERS
  - Liquid phase epitaxy (MOCVD)
  - Diffusion
  - Lithography
  - Bonding
  - Packaging
  - Testing

- PASSIVE/IOSA
  - Magnetron sputtering
  - 1μm lithography
  - Index/thickness measurements
  - SAW measurements

SPEAKER: G.L. YIP
DEPARTMENT OF ELECTRICAL ENGINEERING
MCGILL UNIVERSITY
MONTREAL, QUEBEC
(ABSENT FROM WORKSHOP)

RESEARCH IN OPTICAL WAVEGUIDES AND OPTICAL COMMUNICATIONS

The overall objectives are to investigate:

1) The basic propagation characteristics of optical fibers for optical communications and sensor applications.

2) The basic electromagnetic properties of various planar optical waveguides and their applications in integrated optics.

3) Various applications of optical fiber systems and their implementations.

SPEAKER: R.I. MACDONALD
COMMUNICATIONS RESEARCH CENTRE
P.O. BOX 11490, STATION H
OTTAWA, ONTARIO K2H 8S2
TEL: (613) 596-9629

GROUP MEMBERS: Dr. R.I. MacDonald, D.K.W. Lam, K.L. Sala

RESEARCH INTERESTS

Activities centre on integrated passive distribution of optical signals in optoelectronic switch matrices and development of switching photo-detectors. Plasma CVD oxides, spin-coated resins and diffused glass and $LiNbO_3$ waveguides, and GaAs broadband photoconductors are under study. Plans include work on laser micromachining and nonlinear phenomena in planar waveguide.

LIST OF FABRICATION AND TEST FACILITIES

Equipment	Purpose/Capabilities
1. Photolithography (under development)	Waveguide Fabrication Optoelectronics Fabrication
2. Optical Broadband Transmission Equipment	
(a) Electronic Test Equipment - Network Analyser - Spectrum Analyser - Sweep Oscillator, etc.	Measurement of Optical Transmission Properties up to 4.5 GHz
(b) Optical Transmitters, Receiver	
(c) Optical Fibre Signal Delivery Apparatus	
3. High Power Lasers YAG Excimer	Under Development Laser Masking and Nonlinear Studies
4. Other Equipment Joule Thompson Refrigerator Evaporation, Diffusion, Fibre Handling	Waveguide and Device Fabrication and Testing
5. GaAs Device Fabrication	Available Through Co-operation of CRC Space Electronics Directorate

SPEAKER: M. SAYER
DEPARTMENT OF PHYSICS
QUEEN'S UNIVERSITY
KINGSTON, ONTARIO K7L 3N6

GROUP MEMBERS: Dr. M. Sayer
Dr. S.B. Krupanidhi
Mr. N.F. Maffei

RESEARCH INTERESTS

Our principal current interest is in the fabrication of films of complex oxides and ferroelectrics using planar magnetron sputtering, although we have done considerable work on oxide films (CeO_2, WO_3, MoO_3) using electron beam deposition.

PROJECTS

Lead Zirconate Titanate (PZT):		SAW devices, optical switching and storage, 100 MHz bulk wave transducers.
Zinc Oxide	:	SAW devices
Lanthanum Nickelate (La_2NiO_4):		catalytic electrodes
Stabilized Zirconia (ZrO_2	:	oxygen sensors

FABRICATION AND TEST FACILITIES

EQUIPMENT	PURPOSE
Vactek 4" plasma magnetron unit	Reactive sputtering
Varian Innovac with 6kW e-gun	Evaporation
Rank "Talystep"	Film thickness
Solartron Frequency Response Analyser	Characterization

SPEAKER: V.M. RISTIC
ACOUSTO-OPTIC RESEARCH LABORATORY (AORL)
FACULTY OF APPLIED SCIENCES AND ENGINEERING
UNIVERSITY OF TORONTO
TORONTO, ONTARIO M5S 1A4
TEL. (416) 978-7001
(ABSENT FROM WORKSHOP)

GROUP MEMBERS: G.R. Dubois, D. Gregoris, W. Jiang, R. Arsenault

RESEARCH

In-diffused Ti on $LiNbO_3$ waveguides, geodesic lenses, modified chirp SAW transducers, submicron camera, butt coupling to thin film waveguides, liquid crystal light valves, surface and bulk wave acousto-optics.

LIST OF FABRICATION AND TEST FACILITIES

EQUIPMENT	PURPOSE
Vacuum System	Deposition of Al, Ti
Vacuum System	Deposition of thin dielectric coatings.
Furnace	In-diffusion of Ti
Crystal Polisher and Cutter	Crystal shaping
Grinder	Formation of geodesic lenses
Camera	Photolithography
Rubilith Cutter	Artwork
Phase Contrast Microscope	Light scattering studies
Microwave Equipment (.1-5) GHz	Diagnostics
Optical Equipment	Diagnostics

SPEAKER: W. YOUNG
LITTON SYSTEMS CANADA LIMITED
25 CITYVIEW DRIVE
REXDALE, ONTARIO M9W 5A7

GROUP MEMBERS: 5

SUMMARY OF RESEARCH INTERESTS

LSL is conducting research on Fiber-Optic Rotation Sensors, ultimately for use in inertial navigation systems. We believe that integrated optic devices will be important components in future FORS and hope to establish a research project to develop appropriate devices, particularly couplers and modulators. LSL is doing no integrated optics work at present.

FACILITIES

None in Integrated Optics.

SPEAKER: H. YAMAUCHI
DEPARTMENT OF ENGINEERING MATERIALS
UNIVERSITY OF WINDSOR
WINDSOR, ONTARIO N9B 3P4
TEL. (519) 253-4232, EXT. 2602

GROUP MEMBERS: Prof. H. Yamauchi
Mr. R.J. White, Graduate Student
Mr. T. Yamashita, Graduate Student
Mr. A.A. Hamida, Graduate Student
Mr. J.W. Robinson, Technologist

RESEARCH INTERSTS AND CURRENT PROJECTS:

Fabrication, characterization and design of nonequilibrium (or metastable) engineering materials, especially materials for electronic devices. Presently, a project of fabricating(by means of a sputtering deposition technique)and characterizing c-axis oriented thin films of $Ba_2Si_2TiO_8$ is in progress. Such a thin film should be piezoelectric and be used in ultrasonic transducers such as surface acoustic wave devices.

FABRICATION AND TEST FACILITIES

EQUIPMENT	PURPOSE AND/OR CAPABILITIES
RF Triode Sputtering Deposition System	Thin Film Fabrication (Simard Tri-Mag Sources)
Ceramics Furnace	Max. Temp: 1700°C, Accuracy: ±3°C (Lindberg 51314)
Vacuum Induction Furnace*	Preparation of metallic alloys (LEPEL)
RF Impedance Analyzer	Freq. Range: 1MHz-1GHz Freq. Step: 100 Hz.200 Hz (HP 4191A)
Transmission Electron* Microscope	Observation of Microstructures (JEOL CX100 with STEM)
Scanning Electron* Microscope	Observation of Microstructures (Bausch-Lomb): NANO Lab 7 with Kevex)

(*Departmental Facilities)

SPEAKER: R. NORMANDIN
NATIONAL RESEARCH COUNCIL
DIVISION OF PHYSICS
OTTAWA, ONTARIO K1A 0R6
TEL. (613) 993-0366

GROUP MEMBERS: R. Normandin, J.F. Young and C. Martel

Using recent discoveries of nonlinear laser light interactions, we are setting up the necessary equipment to study and measure surface interactions such as dynamic line shift, and Doppler-free spectroscopy of atoms interacting with surface polaritons at an interface or with an optical waveguide mode. Other projects involving guided waves include optical soliton propagation in the evanescent coupling of a guided mode, the transient coupling of infrared guided modes in semiconductors via optically generated free carrier density gratings, and also a new and accurate method for diffused waveguide profile measurements using nonlinear interactions.

LIST OF FABRICATION AND TEST FACILITIES

EQUIPMENT	PURPOSE
Ion and neutral atom bombardment deposition system and atom mill with online thickness monitor and mass spectroscopy	fabrication of waveguides and experimental chamber
Ellipsometer	thickness measurement of multilayer films
1 J Nd-YAG laser with doubler and tripler with dye laser	laser desorption at surfaces and gratings
CW Nd-YAG laser (also mode locked)	semiconductor waveguide experiments
evaporator system	metal films deposition

SPEAKER: L.G. ROWLANDSON
E.W.D., NATIONAL DEFENCE HEADQUARTERS
DEFENCE RESEARCH ESTABLISHMENT
OTTAWA, ONTARIO K1A 0Z4

GROUP MEMBERS:

Mr. L.G. Rowlandson	- Technical Supervisor
Dr. N. Brousseau	- Principal scientist on Integrated Optics
Mr. J. Lee	- Principal scientist on Bulk Optics
Mr. J. Mickeal	- Principal scientist on Data Processing.

APPLICATION OF ACOUSTO-OPTIC TECHNOLOGY TO MILITARY REQUIREMENTS

The DREO interest in Integrated as well as Bulk Acousto-Optics is applications oriented, in particular, for the development of techniques to detect and analyse RF signals.

Since we do not have the resources to develop components and material we depend upon the knowledge and facilities of University and Commercial agencies to advance the state-of-the-art.

To this end, we are currently funding research at the Universities of Toronto (Ristic) and Waterloo (Chamberlain) and at BNR (Westwood) and RCA (McIntyre).

To date, we have concentrated on applying Bulk technology due to the maturity and availability of this technology. However, Integrated Optics will be of increasing importance because of the need to develop small, light-weight, systems which can sustain a high degree of vibration and other physical effects.

Acousto-optics technology, in general, is high on our list of priorities for development and application primarily because it permits the frequency spectrum and autocorrelation function of complex signals to be derived in near-real time, as examples.

SPEAKER: D. IRVINE-HALLIDAY
DEPARTMENT OF ELECTRICAL ENGINEERING
THE UNIVERSITY OF CALGARY
2500 UNIVERSITY DRIVE N.W.
CALGARY, ALBERTA T2N 1N4
TEL. (403) 284-5941

GROUP MEMBERS: Mr. Abraham Fapojuwo, M.Sc. Graduate Student
Ms. Anjali Agarwal, M.Sc. Graduate Student

RESEARCH INTEREST AND CURRENT PROJECTS

Major research interest centered on the design, fabrication and analysis of a full-access non-blocking optical matrix switch for fibre optic communication networks. VLSI fabrication the ultimate goal.

The time-division multiplexer capabilities of such a switch are of great interest.

Current project-thermooptic switching capability of different materials.

FABRICATION AND TEST FACILITIES

EQUIPMENT	PURPOSE AND/OR CAPABILITIES
EDWARDS S150A SPUTTER COATER	Dedicated Gold Sputtering
EDWARDS 306	Can Sputter Coat and ion beam etch as well as evaporate different metals.

SPEAKER: A.W. LIGHTSTONE
MEMBER RESEARCH AND DEVELOPMENT STAFF
RCA INC., ELECTRO-OPTICS DEPARTMENT
STE-ANNE-DE-BELLEVUE, QUEBEC H9X 3L3
TEL. (514) 457-9000

Management (at this location):

R.G. Power, Director, Solid State Emitters & Detectors
P. Mahaffy, Manager, Finance and MIS
R. Swarbrick, Manager, Marketing Solid State Emitters & Detectors
G. Symeonides, Manager, Materials and Services
R.J.McIntyre, Manager, Research and Development
T. Doyle, Manager, Engineering and Manufacturing
R.P. Oorlynck, Manager, Manufacturing
L. Fortin, Manager, Industrial Relations

The RCA Electro-Optics Department at Ste-Anne-de-Bellevue employs over one hundred people including approximately twenty-five scientists and engineers. The responsibility of this department is the research, development, and manufacture of solid state photodiodes and photodiode-preamplifier modules, especially: silicon photodiodes and silicon avalanche photodiodes (for wavelengths to 1.06 microns) and InGaAs photodiodes (for 1.3 and 1.55 micron fibre optic systems). Typical development projects are ultra-low noise APD's, avalanche photodiode arrays, and customized photodiode and photodiode-preamplifier modules using low-noise hybrid preamplifiers with bandwidths up to 200MHz. A close working relationship exists with other RCA activities, such as corporate research facilities at the David Sarnoff Laboratories in Princeton, N.J., and the CCD group and solid state laser group in Lancaster, PA.

FABRICATION AND TEST FACILITIES	PURPOSE AND/OR CAPABILITIES
Photomask Aligners, Diffusion Ovens, Plasma Etching Equipment, Computerized Ellipsometer, Wafer and Ceramic Scribing and Sawing Equipment. Evaporators, etc. VPE reactor (on order)	Silicon and InGaAs diode fabrication
Ultrasonic bonders, Resistance and Seam Welders, He leak Detectors, etc.	Hybrid Fabrication Hermetic Sealing
Various Electronic and Optical Equipment: Fast Amplifiers, Computer Controlled Positioners, 275MHz Storage Oscilloscopes, 14GHz Sampling Oscilloscope, Spectrum Analysis, Signal Generators, Burn-in Ovens and Jigging, Centrifuge and Environmental Chambers, Optical Benches.	Research, Measurement, and Quality Control
Precision Lathe, Milling Machine	Machining including Custom Photodiode Packages
Library, Computer Facilities	Engineering, Research and Development

SPEAKER: J. MCMULLIN
OPTICAL COMMUNICATIONS RESEARCH GROUP
DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA T6G 2G7
TEL. (403) 432-3332

GROUP MEMBERS:

Paul A. Goud	(Prof.)	(X3940)
Colin G. Englefield	(Prof.)	(X5964)
George D. Cormack	(Prof.)	(X3334)
James N. McMullin	(Assoc. Prof.)	(X5780)

GRAD STUDENTS:

S. Das, S. Mysore, C. Kelly, A Prystajecky, K. Teo, H. Ho, R. Anderson, D. Jodoin

CURRENT (a) AND FUTURE (b) RESEARCH INTERESTS:

Dr. Goud - (a) Multi-level coding for O.F.C., model distortion and microbending losses, linearization of laser-diode transmission characteristics, atmospheric optical link.

(b) High speed O.F.C. electronics, integrated electro-optics.

Dr. Englefield - (a) Ultra-low-noise GaAsFET micro-wave amplifier (for radio astronomy application).

(b) High speed O.F.C. electronics, integrated electro-optics.

Dr. Cormack - (a) 350 Mbaud laser driver, OTDR, coherent communications, directional coupling and switching.

(b) High bit-rate O.F.C., WDM, F-O Sensors, integrated devices.

Dr. McMullin - (a) Numerical methods for light propagation, laser-fibre coupling, etched fibre T and star couplers.

(b) Design and simulation of passive and active devices.

FACILITIES:

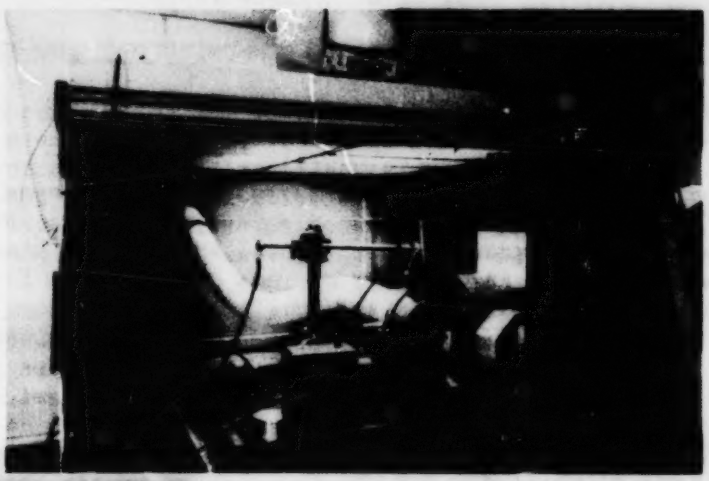
Fabrication:
CAD-CAM System
Ultra Precision Lathe
(brochure included)
Optics Workshop

Test:
Monochromators
300 MHz Sampling Scope
150 Mbaud BER test set
On-line date acquisitions
w/F.F.T for O.F. systems

PRECISION OPTICS
MICROSURFACE GENERATING LABORATORY

DIAMOND MACHINING SERVICES

The University of Alberta MICROSURFACE GENERATING LABORATORY provides contract precision optics services. The Laboratory uses a Pneumo Precision CNC Microsurface Generating Lathe capable of machining surfaces to finishes of better than 1 microinch (250Å).



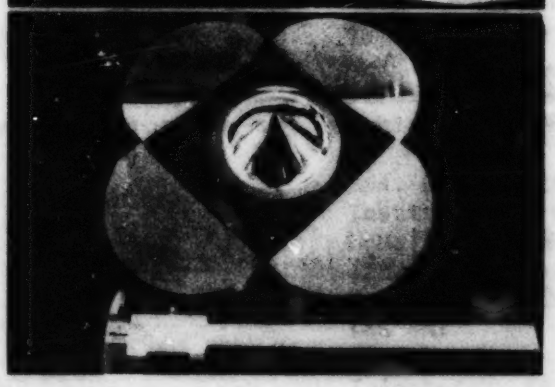


Figure accuracies are equally impressive: typically $\lambda/10$ at 600 nm. The lathe provides an ideal high speed, low cost method for generating optics for use in the infrared range of the spectrum.

Typical applications include optical mirrors (flat, aspheric or parabolic), laser reflectors, prisms and beamsplitters, and waveguides.

Services provided by the Laboratory include design, machining, and testing. Single and prototype quantities are welcomed and production quantities will be considered.

ENQUIRIES ARE INVITED

Contact:
University of Alberta
Electrical Engineering Department
Room 248 Elect./Eng. Building
University of Alberta
Edmonton, Alberta T6G 2G7
Phone (403) 432-4645 or 432-3332

SPEAKER: P.E. JESSOP
MCMASTER UNIVERSITY
DEPARTMENT OF ENGINEERING PHYSICS
HAMILTON, ONTARIO L8S 4M1
TEL. (416) 525-9140

GROUP MEMBERS: B.K. Garside (Ext. 4926)
P.E. Jessop (Ext. 4928)
J. Reid (Ext. 4931)

CURRENT RESEARCH IN OPTICAL COMMUNICATIONS AND INTEGRATED OPTICS

Ultrafast Detector Development: Heterojunction detectors such as Ge-GaAs (where there is a near perfect lattice match) are being fabricated. Pentenary chalcopyrite semiconductor alloys, $Cu_{(1-y)}Ag_yIn Se_{2(1-x)}Te_{2x}$, are being studied in both bulk and thin film form. These materials will then be used for narrowband heterojunction detectors in the 1.0-1.3 μm wavelength region.

Laser Source Investigation: The operation of GaAlAs diode lasers is being investigated on a picosecond time scale. Electrical and optical feedback schemes are used to achieve ultrashort pulses and detailed theoretical modelling is used to predict dynamical behaviour.

Thin Film Waveguides: GeO_2 thin film waveguides have been fabricated with losses below 1dB/cm. Narrowband grating filters have been formed by optically inducing local changes in the films index of refraction. CO_2 laser annealing of GeO_2 waveguides is currently being investigated.

Ion Implantation and Laser Annealing in GaAs: New work is planned (in collaboration with Dr. D.A. Thompson) to study electrical and optical properties of laser annealed, ion implanted GaAs.

FACILITIES

- Thin film deposition - Sputtering
  Evaporating
  Hot Wall Epitaxy
  Liquid Phase Epitaxy
- Transmission electron microscope, scanning Auger/SIMS spectrometer
- X-ray - Powder diffractometer
  Laue systems
- Lasers - CO_2
  - Argon ion
  - N_2, dye
  - GaAlAs diode lasers
  - Lead-salt tunable diode lasers
- Ultrafast optical detectors and electronics
- Photolithographic equipment
- Ellipsometer
- Ion implantation accelerators
- Institute for Materials Research (more detailed information on this 'facility' is to be found on the following page).

McMASTER UNIVERSITY
Institute for Materials Research

1280 Main Street West, Hamilton, Ontario, L8S 4M1
Telephone: (416) 525-9140 Ext. 4683
Telex: 061-8347

Institute for Materials Research

McMaster University

The interaction between industrial companies/research groups and the Institute for Materials Research takes place in two ways. As many as six companies are "adopted" each year by the Institute as Industrial Affiliates. An Affiliate pays an annual fee of $5000 and, in return, its personnel are given full access to the experimental facilities of the Institute at user rates which are the same as those charged to University members of the Institute.

Each year, as many as 30 industrial companies bring "one-shot" problems to the Institute for possible solution. If a solution requires the use of Institute facilities and technical assistance, a charge is made for the service at a rate that is usually 2½ times that assessed to Institute members for the same service.

All inquiries for assistance should be addressed to:

Mr. D.S. Hodgson, Technical Coordinator,
Institute for Materials Research,
McMaster University,
1280 Main Street West,
Hamilton, Ontario.
L8S 4M1

Telephone: (416) 525-9140, ext. 4071.

The experimental facilities of the Institute are listed in its Annual Report, a copy of which may be obtained from:

Mrs. S.J. Williams,
Institute for Materials Research,
McMaster University,
1280 Main Street West,
Hamilton, Ontario.
L8S 4M1

Telephone: (416) 525-9140, ext. 4683.

II WORKSHOP DISCUSSION

DISCUSSION FORUM

In the second part of the meeting the participants in the Workshop on Integrated Optics now formed a rather large discussion group. No agenda had been prepared in advance for this part of the meeting. It was desired that those gathered would themselves decide what should be discussed. What follows is a sort of precis or rapportage of the main topics which surfaced. No attempt will be made to identify the individuals whose views and comments are here presented but only to fairly summarize what was said in several theme areas which were identified and organized 'post-facto'. As editor of these proceedings, I wish to thank all who participated and thus provided the material here set forth. I also would ask the indulgence of any whose comments or views I may have inadvertently misreported.

J. Legendre
Editor

Moderator: Professor John Lit
Physics Department
Sir Wilfrid Laurier University
Waterloo, Ontario N2L 3C5

WHAT DO PEOPLE UNDERSTAND BY INTEGRATED OPTICS

The term integrated optics was coined with respect to integrated electronics. By analogy, integrated optics is taken to mean that field where in the optical components are fabricated in a planar geometry. One reason that defining the field remains uncertain today is that it has developed very slowly. The fabrication of necessary building blocks has been demonstrated (waveguides, lenses, gratings, interferometers) but the successful integration into a larger structure which performs a useful function has yet to be achieved. The reason for the evidently slow progress is that the state-of-the-art is pushed to the limits for any one of the elemental building blocks. Others would argue that examples of integrated optic applications already exist (viz opto-electronic matrix switch). They prefer the descriptions Integrated Opto-Electronic Circuits (I.O.E.C.) when referring to this area of technology. In this definition optical components are integrated with electronics. The optic portions might be very simple and passive components (eg. a waveguide network). Certainly, whichever definition is used, the achievements to date have been modest in terms of actual applications although not in terms of the obstacles which had to be overcome. Why then, in view of these obstacles, should anyone do research in this area?

WHAT ARE THE MAJOR POTENTIAL APPLICATIONS OF INTEGRATED OPTICS

Probably the largest market for this technology will materialize with the advent of coherent communication systems. Already the available microwave bandwidth is being exhausted in many areas. There are presently not enough frequency allocations for large cities. Not only has the demand for traditional services increased (eg. numbers of television channels)

but new services are being proposed (eg. high resolution television, telidon-like information services) which require larger bandwidths than the existing allocations.

Developments in Integrated Optics will certainly affect the emerging and rapidly growing area of optical computing. In this field computations are performed by manipulating photons rather than electrons. Advantages include compatibility with the above-mentioned optical communication systems, as well as utilizing elements likely to be developed for signal processing applications discussed below. Furthermore, some architectures retain the significant benefits offered by parallel optical processing techniques.

Another important domain which will require the advantages promised by Integrated Optics is that of fast signal processing. The most urgent requirements at the moment come from the defence community where the need is for real-time complex signal processing. These requirements include, but are not limited to, devices capable of providing spectral analysis, direction finding, signal correlation, filter and delay functions. It is assumed in that environment that a signal will exist for a very brief period of time and must be detected, analysed and located. It is frequently a further requirement that these functions be provided in a small package (low power and small weight). There is at present no other technology which promises to be fast enough to meet these needs.

The rapidly expanding field of sensor technology is another area which will drive development in Integrated Optics especially when combined with developments in fiber optics. Optically based sensors of various types have unique advantages to offer. The sensors can be configured to give a high degree of immunity to radio-frequency interferences. When used strictly as a communication medium, optical fibers can provide convenient access to regions of very high electric and magnetic field potentials without disturbing these fields. In biological situations, optical sensors are chemically inert and thus may be biologically benign. They

are usually small with consequent minimization of tissue insult. If communication with the probe is by optical fiber, risk of electric shock is eliminated. Optical sensors based on some variation in light intensity can easily be made environmentally robust. Optical sensors based on some interference technique are more difficult to shield from undesired disturbances but offer the potential for much greater sensitivity. Finally, optically based sensors will likely offer significant cost advantages in many situations.

In a general sense, it was stressed that one of the very best ways in which optics can be used is for isolation. Opto-electronic matrix switches have been reported which provide 80 db isolation (on/off power ratio) for example.

Several of the advantages already mentioned should mean that optical devices of various sorts (i.e. high speed signal processing, isolation, small mass and low power consumption, sensing) should find application in satellite packages.

Another potential area of interest which emerged involved the interconnection problem with very large scale integrated circuits. Reference was made to a suggestion originating from J.W. Goodman et al[1] for an optical solution to this growing problem. This involves the possibility of using a hologram located above a chip, illuminated by a laser at the edge. The light beams could access different parts of the chip by free space propagation.

With such quantity of desirable characteristics, why has the field not developed more rapidly than it has?

WHAT ARE SOME MAJOR PROBLEM AREAS IN INTEGRATED OPTICS?

One fundamental problem is that materials which are good at some things are not good for other things. Materials such as gallium arsenide are

good light generators but have a much lower electro-optic coefficient than insulating crystals such as lithium niobate and lithium tantalate. If the goal is to achieve a monolithic integrated optical circuit wherein all optical functions (light generation, coupling, amplification, guiding, modulation and detection) are potentially present, then the likeliest approach is to use a single material although Si on GaAs is now possible. At present a lot of attention is being directed at the family of III-V semiconductor compounds. All of the optical functions mentioned above have been demonstrated in gallium arsenide. Most functions have also been demonstrated using II-VI semiconductors. Zinc oxide, for example, is electro-optic, has a large piezoelectric coefficient and has been doped to become a photoconductor.

Another difficulty is that guided-wave optics transmission is affected by first-order scattering effects whereas the interesting electro-optic effects are of second-order. The technological problems are perhaps several orders of magnitude more difficult in optics. While it may be easy 'to do electronics', it may be fundamentally very hard 'to do optics'.

Another problem which has yet to be adequately addressed is the area of basic materials characterization. Devices have tended to be fabricated on a cut and try basis. Interest has perhaps centered on a few parameters and even that interest often dissipates when device performance has reached an acceptable level. An example of this state of affairs is illustrated by the lack of in-depth knowledge of titanium indiffused waveguides in Lithium Niobate in spite of the very large numbers of guides which have been fabricated with this material throughout the world. In this connection, it was stressed, however, that material characterization of thin film structures is a difficult matter. A trace element at a concentration of one part per million in a cubic centimeter is hard to find; one part per million in a 1000A° film is extremely hard to find. A great deal of work is required in the area of materials characterization and material properties to really determine

how devices work. Improved understanding of materials will lead to improve performance of devices and to new devices just as it has been in the silicon industry which has made enormous advances in thirty years. The sorts of things that are being done in V.L.S.I. circuitry could never have been done twenty years ago due to impurities, dislocation densities etc. in silicon. Research in Integrated Optics using existing or new materials should be considered from that point of view.

It was pointed out that really powerful instrumentation to characterize materials has been around for years. It is usually lack of interest or time which limits in-depth characterization of integrated optic materials. At present, it is not necessary to look for new instrumentation but to effective use of existing instrumentation. It was also pointed out that even with a sophisticated M.B.E. machine the problem of characterization still exists.

POTENTIAL STRATEGIES FOR WORKERS IN INTEGRATED OPTICS IN CANADA

As this field of research begins to slowly mature, it is a field in which it is becoming more expensive to compete effectively. The fundamental nature of many of the major obstacles to further progress in the area of integrated optics means that much more effort must be expanded if truly integrated devices are to be achieved. Integration, of itself, is a goal which will require, as it has in other disciplines, the participation of many areas of expertise.

Clearly it would be beneficial to organize collaborative efforts, for example, between groups that are interested in devices on the one hand and groups that are interested in materials characterization on the other hand.

There was some feeling at the meeting that while collaborative projects were desirable and more necessary that ever, it was recognized that such cooperation is not easily established. It was also clear that most

present at the meeting were not aware of the existence of mechanisms whereby collaborative activities could be initiated particularly in connection with government laboratories.

N.R.C.: It was stated that the N.R.C. had perhaps the most powerful analytical facility in the country for research purposes and that it would certainly make sense to build on an existing core of expertise. It was clear that there are problems with this approach. The Council consists essentially of researchers whereas the country requires that a problem solving approach be adopted if interaction with outside organizations is to be attractive. Also, for the Council to become more involved with outside groups, staff support is crucial. Typically as areas of research move on, the base support activities are not maintained. But it was stated that even within the present framework - that N.R.C. is trying. It must be realized that if a research tool exists, it is being used for something else and the operator does not want someone else's hands on the knobs. Essentially a potential collaborator from outside must persist and the 'insider' must relax a little. One suggested mechanism for realizing collaboration with the N.R.C. is that of the Guest Worker: in this case an outside researcher, having established that an area of mutual interest exists, might come to the Council's laboratories to contribute his own serious, sustained effort (e.g. 3 months). An example of the agreement used in such cases is given in Appendix A. Another route which may also generate effective collaboration is for outside workers to make suggestions on research proposals that would generate interest within a particular N.R.C. laboratory. Essentially both groups must be interested in very similar systems (e.g. guides in $LiNbO_3$ - the interest in common might be the material not necessarily the application of the material). Yet another mechanism is the possibility of purchasing services from the N.R.C. An example of the application form to be used together with its conditions is given in Appendix B.

C.R.C.: within this organization the Space Electronics Section would probably be the group having the most facilities relevant to workers in this area. Facilities exist for fabrication (GaAsFET - microlithography done on commercially grown material) and for materials characterization (scanning Auger, scanning electron microscope, Hall effect measurements).

Contact: Dr. J.G. Chambers
Director General
Space Technology and Applications
Communications Research Center
3701 Carling Ave, P.O. Box 11490, Station 'H'
Ottawa, Ontario K2H 8S2, Tel: (613) 998-2009

Surface Science Western/Guelph-Waterloo Surface Science & Technology Groups: It was stated that these centres had the most advanced surface analytical facilities in the country. Surface techniques include: scanning electron microscopy with energy dispersive X-ray analysis, X-ray photoelectron spectroscopy (ESCA), scanning Auger microscopy, secondary ion mass spectrometry, photo-acoustic spectroscopy, Rutherford backscattering spectrometry, particle induced X-ray emmission, surface enhanced Raman spectroscopy, reflectance infrared spectroscopy. Arrangements can be made for long term contract work to meet a continuing need or for short term service work to respond to a particular problem. Joint contracts involving both Surface Science Western and the Guelph-Waterloo Centre can also be arranged. Further information can be obtained by contacting either or both of the following persons:

at Surface Science Western:
Ms. Darlene Johnston
Room 6,
Natural Science Center
The University of Western Ontario
London, Ontario N6A 5B7
(519) 679-2233

at Guelph-Waterloo Surface Science & Technology Group:
Dr T. Craig
Dean's Office
College of Physical Science
University of Guelph
Guelph, Ontario N1G 2W1
(519) 824-4120, Ext. 3640

Other organisations from which relevant services would be available.

Organizations mentioned at the meeting in this connection were the following:

Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario L5K 1B3

Contact: Mr. D.R. Hollingbery
Customer Service and Information Coordinator
(416) 822-4111

Facilities include electron microscopes with energy dispersive x-ray analysis, microprobe analysis (wavelength dispersive x-ray), transmission electron microscopes (resolution to approximately 0.2 nm), as well as a range of optical microscopic techniques.

QRL Analysis Corp.
19 Grenfell Cr., Suite 100
Nepean, Ontario, Canada K2G 0G3
Tel: (613) 226-1885

Services

- Scanning electron microscopy with X-ray energy dispersive system
- scanning Auger microprobe and secondary ion mass spectroscopy
- failure analysis
- X-ray radiography
- destructive failure analysis
- optical microscopy
- sample preparation, sectioning and polishing
- X-ray microprobe analysis with wavelength dispersive spectrometers.

Precision Photomask
4950 Fisher Street
Ville St-Laurent, Quebec H4T 1J6
(514) 676-0748

Services

- Photomasks for V.L.S.I., acoustic surface wave devices, optical waveguides, hybrids, microwave circuits
- photo-plotting for P.C. boards.

Equipment

- Gerber photo-plotter
- pattern generator
- step and repeat camera (linewidths down to 0.8 μm).

The question was raised as to whether there were any facilities which do not now exist in the private sector and for which there might be sufficient demand. It was pointed out that, while facilities existed for making masks, none were yet producing actual circuits on a custom basis. There was some encouragement voiced for those who would consider entering the services field. Start-up costs need not be very large. The important thing was to try something modest at the start.
Finally it was suggested that graduate-level courses or short (one week), intensive courses at various locations might be offered as a means of promoting increased activity in this field in the country. Also, opinions were solicited regarding the desirability of looking to a Canadian conference on the theme of Integrated Optics or perhaps a conference covering the fields of Optical Fibre Communications & Integrated Optics or yet again, in view of the discussions reported, a conference on Integrated Optics Devices & Materials. Regretably, no concensus from the meeting on any of these proposals, was forthcoming. Perhaps one of these suggestions might now be considered ripe?

The moderator then declared the session closed.

REFERENCE

(1) Joseph W. Goodman, Frederick T. Leonberger, Sun-Yuan Kung & Ravindra A. Athale, "Optical Interconnections for VLSI Systems". Proc. IEEE, Vol. 72, No. 7, pp 850-866, July 1984.

APPENDIX A

An example of the Agreement entered into by Guest Workers at the National Research Council

National Research Council Canada / Conseil national de recherches Canada

GUEST WORKER AGREEMENT / ACCORD CONCLU AVEC UN TRAVAILLEUR INVITÉ

Name of Guest Worker	_____	Nom du travailleur invité
Present Employer (if any)	_____	Employeur actuel (s'il y a lieu)
To work in Division/Branch of	_____	Division/Direction où se fera le travail
To work with	_____	Personne(s) avec qui se fera le travail
Duration	_____	Durée

It is understood and agreed that the National Research Council has granted me permission to be present in its facilities to work in the Division/Branch and with the person(s) described above for the period of time set out above as a guest worker. It is further understood and agreed that the National Research Council maintains the right to determine and impose the terms and conditions on which I may be present in its facilities and that:

1. The National Research Council will not pay me any salary or expenses during this period.
2. I waive the right to bring any claim, demand or action, including an action for damages based on a claim of negligence against the National Research Council or any of its officers, agents or employees, which may arise as a result of any incident which occurs during my presence in the National Research Council's facilities as a guest worker or as a result of the activities I undertake related to the work I am doing during my visit with the National Research Council.
3. I will not publish any material involving work carried out during my visit at the National Research Council without obtaining the prior approval of the Director of the Division/Head of the Branch in whose Division/Branch I am working.
4. This arrangement may be terminated at any time by myself, or by the Director of the Division/Head of the Branch in which I am working.

Il est entendu et convenu que le Conseil national de recherches m'a accordé la permission d'être présent dans ses locaux pour travailler dans la division/direction, avec la(les) personne(s) et pour la durée précisée ci-dessus à titre de travailleur invité. Il est entendu et convenu en outre que le Conseil national de recherches maintient le droit de déterminer et d'imposer les conditions auxquelles je pourrai être présent dans ses locaux et que:

1. Le Conseil national de recherches ne me paiera aucun traitement ni aucune dépense au cours de cette période.
2. Je renonce au droit d'effectuer quelque réclamation, de présenter quelque exigence et d'intenter quelque poursuite en dommages-intérêts que ce soit qui se fonde sur une allégation de négligence contre le Conseil national de recherches ou contre l'un ou l'autre de ses agents, représentants ou employés pouvant résulter d'un incident survenu au cours de ma présence dans les locaux du Conseil national de recherches à titre de travailleur invité ou des activités que j'entreprendrai dans le cadre du travail effectué par moi au cours de ma visite au Conseil national de recherches.
3. Je ne publierai aucun texte sur le travail effectué au cours de ma visite au Conseil national de recherches sans en avoir obtenu au préalable l'approbation du Directeur de la Division/Chef de Direction de la Division/Direction où je travaillerai.
4. Il pourra être mis fin au présent accord à n'importe quel moment par moi-même ou par le Directeur de la Division/Chef de Direction de la Division/Direction où je travaillerai.

Signed / Signé

_____

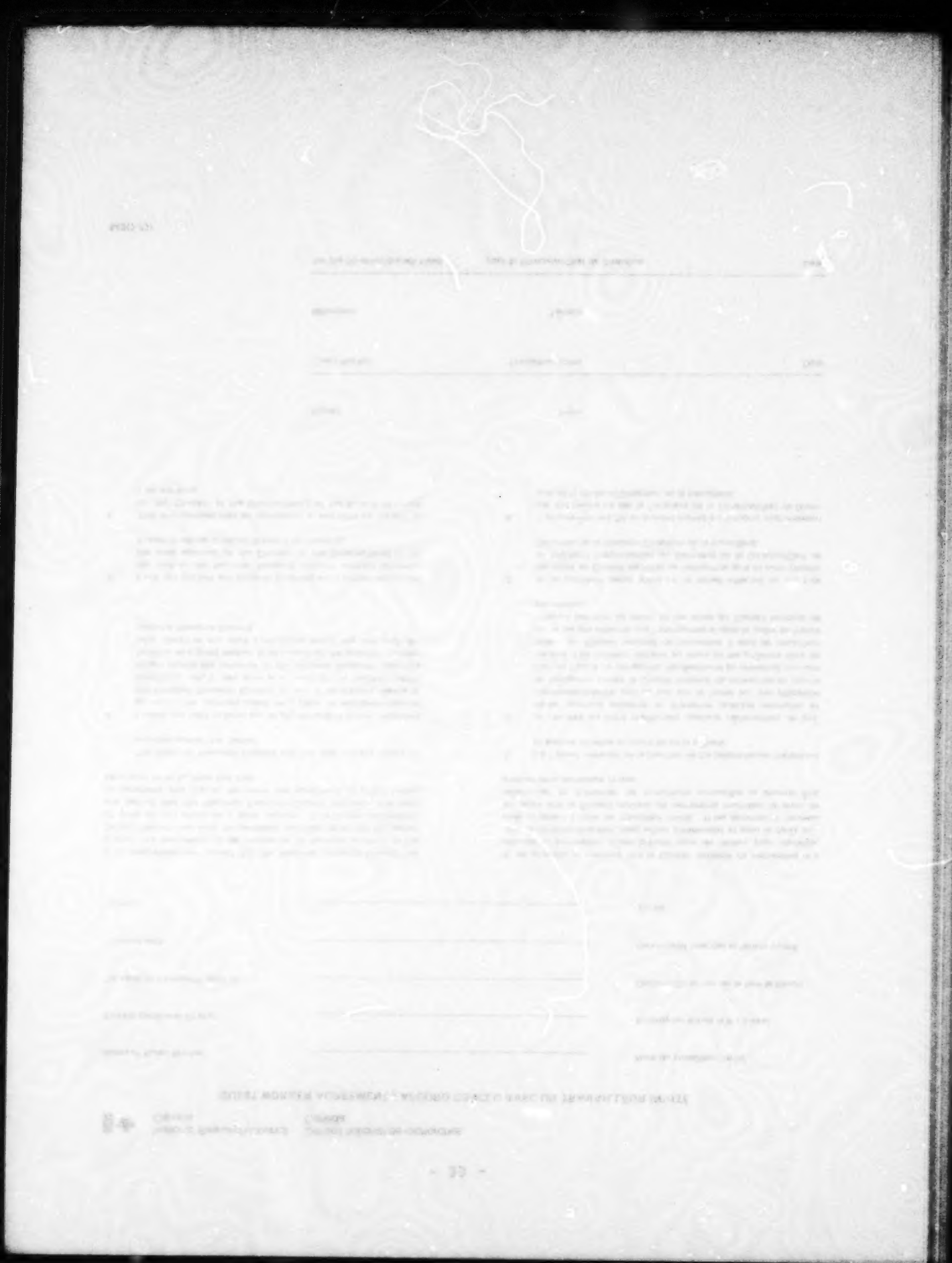
Guest Worker / Travailleur invité — Date

Witnessed / Témoin

_____

for the Director/Branch Head / pour le Directeur/Chef de Direction — Date

5421(7-77)



APPENDIX B

An example of the form to be used when requesting a service from National Research Council

National Research Council Canada | Conseil national de recherches Canada

NRC FILE NO./N° DE DOSSIER DU CNRC	
DIVISION	
PROJECT NO./N° DU PROJET	

APPLICATION TO THE NATIONAL RESEARCH COUNCIL OF CANADA FOR STANDARDIZATION, TEST, INVESTIGATION OR OTHER SERVICE

DEMANDE AU CONSEIL NATIONAL DE RECHERCHES DU CANADA D'ÉTALONNAGE, D'ESSAI, DE RECHERCHE OU D'AUTRES SERVICES

By: _____ (The "Applicant" /le « demandeur »)
Présentée par : (Name/ nom)

_____
(Address/ adresse)

_____

1. The following Service is requested subject to the Conditions of Service on the back of this Application:
La service ci-après est demandé aux conditions énumérées au verso de la présente :

Estimated Cost / Coût estimatif $ _____

2. Number of copies of report requested: _____ (See Condition 2.)
Nombre requis d'exemplaires du rapport : (voir la condition n° 2)

3. For the Service requested: (Strike out (a) or (b) — rayer la modalité rayetée)
Pour le service demandé :
(a) a prepayment on account of the fee payable in the amount of _____ $ _____
un paiement anticipé sur le compte dû d'un montant de
est annexé à la demande (voir la condition n° 4.)
(b) billing and payment on receipt of invoice. (See Condition 1.)
le paiement se fera sur réception de la facture (voir la condition n° 1.)

4. Is the Applicant's property to be returned? _____ (See Condition 7.)
Les produits du demandeur doivent-ils être renvoyés? (voir la condition n° 7.)

5. End purposes of the results of the Service requested:
Objectifs finals des résultats du service demandé :

.....

.....

6. The Applicant acknowledges that NRC does not wish to compete with any organization in the Canadian private sector or any other organization, public or private, whose income is derived from research contracts.
The Applicant is not prepared to have any other organization perform the service described in this Application for the following reasons:
Le demandeur reconnaît que le CNRC ne concurrence aucun organisme du secteur privé ou public canadien ni aucun établissement public ou privé dont les revenus sont tirés de contrats de recherche.
Le demandeur n'a pas l'intention de s'adresser à d'autres organismes pour assurer le service décrit dans la présente demande pour les raisons suivantes :

.....

.....

.....

_____
Signature of Applicant
Signature du demandeur

Per
Par _____

_____
Position with Applicant
Titre

_____
Date

_____
Date

SEE CONDITIONS ON REVERSE SIDE
VOIR LES CONDITIONS ÉNUMÉRÉES AU VERSO

32 (8-83)

Canada

CONDITIONS OF SERVICE

1. All fees for Service shall be paid net cash in NRC's sole discretion, either in arrears, by instalments or in advance of the provision of the Service by NRC as required by invoices based on the NRC fee schedule in effect on the date of this Application or pursuant to Condition 3.

2. An additional fee will be paid for extra work required to make the Applicant's property ready for the Service to be rendered and for all repairs on the Service in excess of this.

3. If a Service does not have a fee prescribed in the NRC fee schedule, the fee may be established on a cost basis. Its estimate shall be binding on NRC.

4. If the deposit in advance is required as per Condition 1, and the deposit is insufficient to pay the whole of the fee payment, the balance of the fee shall be paid upon receipt of invoices, by progress payments in advance of the work being executed.

5. Transportation, packing, customs and other costs and charges shall be paid by the Applicant.

6. Property of the Applicant shall be delivered to NRC in a condition such that it will not injure or damage NRC employees or property.

7. After performance of the Service requested, and on the request of the Applicant, NRC will return the Applicant's property to it at the Applicant's expense; otherwise the property will be dealt with by NRC as it sees fit.

8. While NRC will use its best efforts to protect property and information in the provision of the Service, it shall not be liable or responsible:
(a) for injury or death, loss or damage to the Applicant, the Applicant's employees or property due to any cause whether negligence or otherwise, and
(b) for keeping the Applicant's property or information relating to it safe whether it is of a confidential nature or otherwise.

The Applicant shall be responsible to insure the Applicant's property at its expense for loss or damage due to fire, theft and all other causes.

9. Pursuant to the Public Servants Inventions Act, all inventions made by employees of NRC during the course of the Service provided by NRC shall vest in NRC.

10. This Application supersedes all communications, negotiations, arrangements, agreements including but not limited to, purchase orders or similar documents submitted by the Applicant for the Service referred to on the reverse side of the Application, and this Application may only be superseded or amended by contract in writing duly executed by the Applicant and NRC.

11. The National Research Council of Canada shall not be used in advertising or promotion whether by use of its name by inference or otherwise.

12. No member of the House of Commons shall be admitted to any share or part of this agreement or to any benefit to arise therefrom.

CONDITIONS RÉGISSANT LES SERVICES DU CNRC

1. Tous les frais de service doivent être payés en espèces, à la convenance du CNRC, sont sous la forme d'acomptes différés ou de versements précédant la prestation des services, sur présentation de factures conformes au barème du CNRC en vigueur à la date de la présente demande ou à la condition nº 3 ci-après.

2. Des frais additionnels sont chargés pour tout travail supplémentaire requis pour préparer les produits du demandeur aux fins du service à assurer et pour tout exemplaire du rapport demandé en sus des deux copies remises.

3. S'il n'existe pas de tarif relatif au service demandé, le CNRC peut imposer un coût estimatif. Le CNRC se réserve le droit de modifier les états estimatifs établis à cet effet.

4. Si un dépôt doit être versé d'avance en conformité de la condition nº 1, mais que le montant est insuffisant pour payer le plein tarif établi, le solde doit être réglé sur réception des factures par paiements échelonnés effectués avant la prestation des services.

5. Les frais de transport, de douane, d'emballage ainsi que tous les autres coûts et charges sont supportés par le demandeur.

6. Les produits du demandeur doivent être livrés au CNRC dans un état qui n'expose pas le personnel du CNRC à des blessures ou ses installations à des dommages.

7. Une fois les services assurés, le CNRC retourne les produits du demandeur aux frais de ce dernier. Le CNRC dispose à sa discrétion des produits non réclamés.

8. Bien que le CNRC s'engage à faire tout en son possible pour protéger les produits et les renseignements relatifs au service, il rejette toute responsabilité en matière
(a) de blessures ou de décès du demandeur ou des ses employés et de pertes ou dommages causés aux produits de ce dernier que ce soit par négligence ou autre et
(b) de protection des produits ou des renseignements du demandeur, qu'ils aient de nature confidentielle ou autre.

Le demandeur s'engage à assurer ses produits à ses frais contre les pertes ou dommages dus à l'incendie, au vol ou à d'autres causes.

9. Conformément à la Loi sur les inventions des fonctionnaires, toutes les inventions faites par les employés du CNRC durant la prestation des services visés par la présente demande sont la propriété du CNRC.

10. La présente demande annule toutes les communications, les négociations, les arrangements, les ententes, y compris mais sans s'y limiter, les commandes d'achat ou autres documents présentés par le demandeur pour la prestation du service décrit au recto de la présente. La demande de service ne peut être annulée ou modifiée que par contrat écrit dûment exécuté par le demandeur et le CNRC.

11. Aucune mention du CNRC ni son nom ne doivent être utilisés à des fins de publicité ou de promotion.

12. Aucun membre de la Chambre des communes ne peut prendre part en tout ou en partie à la présente entente ni retirer des profits qui pourraient en découler.